Article

The Nexus between Carbon Emissions, Energy Use, Economic Growth and Financial Development: Evidence from Central and Eastern European Countries

Alina Georgiana Manta [1],*, Nicoleta Mihaela Florea [1], Roxana Maria Bădîrcea [1], Jenica Popescu [1], Daniel Cîrciumaru [1] and Marius Dalian Doran [2]

[1] Department of Finance, Banking and Economic Analysis, Faculty of Economics and Business Administration, University of Craiova, 13 A.I. Cuza Street, Craiova 200585, Romania; nicoleta.florea@edu.ucv.ro (N.M.F.); roxana.badircea@edu.ucv.ro (R.M.B.); jenica.popescu@edu.ucv.ro (J.P.); daniel.circiumaru@edu.ucv.ro (D.C.)

[2] Doctoral School of Economic Sciences, Faculty of Economics and Business Administration, University of Craiova, 13 A.I. Cuza Street, Craiova 200585, Romania; doran.dalian@yahoo.com

* Correspondence: alina.manta@edu.ucv.ro

check for updates

Abstract: The aim and novelty of this study consist of estimating the nexus between CO_2 (carbon dioxide) emissions, energy use, economic growth, and financial development for ten Central and Eastern European countries (CEEC) over the 2000–2017 period, starting from Environmental Kuznets Curve (EKC) theory. The Fully Modified Ordinary Least Squares (FMOLS) method was used for testing the cointegration relationship. Granger causality estimation based on the Vector Error Correction Model (VECM) and Pairwise Granger causality test were applied to identify the causality relationships between the variables and to identify the direction of causality. The implementation of the tests led to significant conclusions. In the long run, the levels of CO_2 emissions and energy use do not have any influence on economic growth. Furthermore, there is a bidirectional causality among economic growth in terms of GDP and financial development variables. Thus, increasing financial development will generate more CO_2 emissions and more energy use, and increasing economic growth will lead to rising financial development. In the short run, increasing financial development will generate more CO_2 emissions and will lead to increased energy use and economic growth. Also, a bidirectional causality is being revealed between financial development and CO_2 emissions. This indicates that financial development may help to reduce CO_2 emissions.

Keywords: climate change; economic system; fully modified OLS

1. Introduction

Extreme climate change developments impact health and infrastructure, diminishing wealth, and lowering productivity. Therefore, these unfortunate circumstances could also affect economic activity and trade, redirecting the productive working capital like technology to rebuild and replace. Unpredictability about prospective casualties could also lead to greater safety measures and fewer necessary investments. Nowadays, physical impacts already have an outcome on the economy and on the financial system. Overall, costs are rising globally due to natural disasters and averaged at $140 billion every year in 7 of the last 10 years [1].

Specialists and researchers [2] forewarn that if no action is taken to reduce emissions, the physical impact of climate change on the international economy will be significant. These studies suggest that medium global revenues may be reduced by up to a quarter. Furthermore, many scientists have pointed out that continuous emissions at high levels would result in warming of 1.5 °C between 2030 and 2052 [3].

Thus, climate change can be considered a systemic risk that affects the financial industry, as it affects all sectors of the global economy. While the industry is varied in its specific functions and activities, all agents have in common a duty of trust to act in the best interests of the people or organizations whose assets are responsible for supervision.

Nevertheless, climate change has deep negative impacts not only on the environment but also on the global financial stability of the countries. Therefore, regional and international authorities, organisations, and governments are making sustainable efforts and they are taking action in order to reduce the climate risks from the financial system and to contribute to develop and implement the appropriate policy framework. Also, some financial institutions are taking action and are making a positive contribution to addressing the climate change challenge.

The important damages produced by the physical outcomes of climate change and the direct connection with the accumulation of CO_2 emissions stimulated the international authorities to take measures to reduce emissions in Paris in December 2015. The Paris Agreement goal is to limit the increase in global average temperatures to below 2 °C above pre-industrial levels and to strive for restricting the temperature rise to 1.5 °C. [3].

Similar actions were carried out by NGFS (Network for Greening the Financial System) [4] in order to mitigate the negative impacts of the CO_2 emissions on the environment and also to identify, assess and reduce climate-related risks. The specialists from NGFS understood the importance of climate change effects on the financial stability and at the initiative of Banque de France, eight central banks and supervisors established the activity of this network (NGFS) in December 2017.

According to Frank Elderson [4], Chair of the NGFS "the first NGFS comprehensive report emphasized that climate-related risks are a source of financial risk and it, therefore, should be identified and quantified by the central banks and supervisors to ensure the financial system is resilient to these risks". The above-mentioned report also pointed out the needs and identified the best practices for a flattened transition to a low-carbon economy.

The transition to a low-carbon economy involves quick and extensive transitions in all systems. Thus, the Intergovernmental Panel on Climate Change (IPCC) outlines the specific additional energy-related investments compatible with a 1.5 °C scenario for the period 2016–2050 in order to access USD 830 billion annually [3]. The European Union (EU) has detected an annual investment gap of almost EUR 180 billion to accomplish its climate and energy targets [5].

Although the growing change in total investment is not high, it could involve an important redirection of capital toward green finance [6]. On one hand, the Organisation for Economic Cooperation and Development (OECD) appreciates that to reach the 2 °C target, financing of the bonds and refinancing in the renewable energy, energy efficiency and low-emission vehicle sectors have the potential to achieve USD 620 billion to USD 720 billion in annual issuance and USD 4.7 trillion to USD 5.6 trillion in outstanding securities by 2035 [7].

On the other hand, Europe's main financial organisations, such as the European Central Bank (ECB), the European Investment Bank (EIB), and the European Bank for Reconstruction and Development (EBRD), which are in a position to advance the European agenda, are also joining the battle to mitigate the impacts of climate change by creating a Climate Bank at the European level [8] and by allocating 30% [8] of their 2018 climate financing to adaptation.

The annual United Nations (UN) Environment Emissions Gap Report [9] presents an assessment of current national reducing efforts and the targets that the countries have presented in their Nationally Determined Contributions, which are also the foundation of the Paris Agreement. Despite growing global awareness of the dangers posed by climate change, fossil CO_2 emissions from energy use and industry, which dominate total greenhouse gas emissions, grew 2.0% in 2018, reaching a record 37.5 $GtCO_2$ per year.

According to the data provided by World Resources Institute specialists [10] carbon dioxide (CO_2) accounts for 74% of greenhouse gas emissions. Most CO_2 emissions (89%) come from the use of fossil fuels, mainly for electricity and heat generation, transport and manufacturing and consumption.

Nevertheless, land use, land-use change, and forestry are another major contributor (7%) to man-made CO_2 emissions, largely due to deforestation.

As for the analysis made by some companies [11], Europe is expected to have the second-largest market size in the following period due to increased investment and funding, and companies are attracting investment to develop green technology solutions for various applications in agriculture, weather, transport, and energy sectors. Rapidly growing economies such as Germany, the United Kingdom, and France are implementing green and sustainable technologies based on strong compliance and regulatory landscape and increasing investment by government and companies to address climate change by implementing technology solutions for different applications. Companies operating in Europe would benefit from flexible economic conditions, government policies driven by industrialization and globalization, as well as growing digitalisation, which is expected to have a huge impact on the business community.

Furthermore, Lee and Mathews [12] emphasize that latecomer countries like the countries analysed in this study, that want to take the lead in green technologies face a variety of other challenges, including cost and trade barriers. Many of the most favourable renewable energy systems, such as concentrated solar power (CSP) (which involves a wide range of lenses and mirrors to concentrate solar energy and store it by means such as molten salt systems), still involve costs that exceed those of dirt and unsafe coal or oil supplies. Costs are declining rapidly (as for solar photovoltaics) and will soon be reduced as China enters the field of CSP. However, smart financial instruments, such as green bonds/climate bonds, can bypass such barriers by lowering the cost of financing by aggregating projects into packages that can be paid for in bond markets.

However, Cloete [13] thinks that the most important issue is that all these green technologies require high capital. In addition, the commitment to an energy future dominated by these technologies also requires a wide range of complex and capital-intensive support investments. This requirement for complex, large investments makes these technologies fundamentally unsuitable for supporting rapid economic development, which is a much higher priority than sustainability for about 80% of the world's citizens.

An International Energy Agency analysis [14] has shown that a broad portfolio of clean energy technologies will be needed to decarbonise all parts of the economy, and in this purpose, batteries and hydrogen-producing electrolysers stand out as two important technologies thanks to their ability to convert electricity into chemical energy and vice versa.

The cost of lithium-ion batteries, in particular, has decreased thanks to higher production volumes and to the fact that the progress of battery technology is more advanced than that of electrolysers. The scale-up of electrolysers manufacturing, on the other hand, is at an earlier stage. However, that makes its scope for significant near-term cost reductions even larger. Governments in many countries have adopted policies encouraging the increased deployment of electric cars, further accelerating the decline in battery prices.

At the same time, the power sector now offers growing opportunities for the use of batteries to support the integration of variable renewables, such as wind and solar PV, into electricity systems. As such, lithium-ion batteries are now a technology opportunity for the wider energy sector, well beyond just transport.

The paper is structured as follows: Section 2 presents a brief review of the literature on the relationship between the CO_2 emissions and financial development, Section 3 describes the variables included in the analysis and the methodology used, Section 4 presents empirical results and discussions and the last section presents the conclusions of the study.

2. Literature Review

There are a plethora of professional papers regarding the link between financial development and the deterioration of the environment. In 1991, Grossman and Krueger [15] advanced economist Simon Kuznets's 1950–1960s theory the Environmental Kuznets curve (EKC), a hypothesis which presents

that as the economy improves it takes a toll on the environment just for it to later reduce the emissions of harmful gases after passing the turning point, Selden and Song [16] attributing this evolution to environmental awareness. Meaning that the evolution of economic development and its effect on the environment is conveyed through a U-shaped function [17].

Since then, there have been both assertive and disavowal opinions surrounding this theory.

Among scholars, there is the assumption that the financial development of a country can have a beneficial impact on the reduction of CO_2 emissions. At the bases of this assumption is the fact that economic growth equals technological development so companies will need to allocate funds for technic improvements so they can compete on the market and improve efficiency. Furthermore, because of the urgency of the situation, referring to global warming, governments tend to support programs and projects that are considered environmentally friendly. Lanoie et al. [18] agree with this particular point has found that the market can minimise CO_2 emissions just by stimulating firms to abide by environmental regulations.

Studies that support this hypothesis are those of Birdsall and Wheeler [19], Frankel and Romer [20], and Frankel and Rose [21] which claimed that economic growth can lead to the implementation of environmentally friendly technology, resulting in carbon emissions reduction. The research of Dasgupta et al. [22], Wang and Jin [23], Bello and Abimbola [24], and Islam et al. [25] certify that financial growth will prompt listed firms to incorporate legislation regarding the preservation of the environment. Ang [26] confirmed the U-shaped function of the EKC in 1960–2000's France's case through in-depth analysis, and Apergis and Payne [27] applied Ang's model demonstrating the evolution of the economy in relation with pollution and energy use. Kumbaroglu et al. [28] stated that economic growth helps to ease the development in the technological domain, particularly the energy sector which can, in fact, reduce the CO_2 emissions.

Claessens and Feijen [29] acknowledge how the financial sector is essential when talking about the emission of CO_2, stating that economic growth is more inclined to promote eco-friendly projects that will consequently reduce pollution.

Another research that tested and confirmed the existence of the Environmental Kuznets curve for different nations are Aldy [30] for certain states of America, Acaravci and Ozturk [31] for European countries, and Apergis and Ozturk [32] respectively, for Asian countries.

There are studies including other parameters that affect CO_2 emissions and that do not take into consideration the financial development variable.

Thus, Hossain [33] investigated the relationship between CO_2, energy consumption, economic growth, trade opening, and urbanization for a group of nine newly industrialized countries that included Malaysia, the Philippines, and Thailand. The study indicates that energy revenues and consumption have a significant long-term impact on CO_2 emissions in the Philippines and Thailand, but not for Malaysia.

Niu et al. [34] analysed the long-term relationship between energy consumption, GDP, and CO_2 for eight Asia-Pacific countries, which included four developing countries, namely China, India, Thailand, and Indonesia, using panel data techniques. For developing countries, there has been a long-term relationship between energy consumption, coal, oil, and CO_2 emissions.

Ghouali Y.Z. et al. [35] examined some of the possible factors that increased CO_2 emissions in six BRICS (acronym created for an association of five major emerging national economies: Brazil, Russia, India, China and South Africa) countries, namely Brazil, Russia, India, China, and South Africa. They used a panel model in the 1990–2012 period. To achieve the objective of the study, a CO_2 emissions model was designed, taking into account CO_2 emissions as a dependent variable and total primary energy consumption, net FDI inflows and GDP per capita, as primary variables.

Bekhet and Mustapa [36] measured the CO_2 emissions of the transport industry in the countries in the "Belt and Road Initiative" (BIS) line. Afterwards, they analysed the influencing factors from 57 BIS countries using the panel data model. The results obtained highlight that GDP per capita, the level of urbanization, and the structure of energy consumption have a positive effect on carbon

dioxide emissions in the transport industry, while the level of technology and the trade openness have a negative effect on carbon dioxide emissions in this industry.

Furthermore, there are more studies emphasizing the nexus between CO_2 emissions and financial development.

Thus, Shahbaz et al.'s [37] research centres on the effects of financial development and energy consumption of CO_2 emissions in Malaysia. The study was conducted over the period 1971–2008 and shows the long-term relationship between the two, as well as the reduction of CO_2 emissions through economic growth and the increase of foreign trade.

Moreover, other works [38,39] admit that financial development improved the level of pollution. Park et al. [40] also concur with the variation of the EKC after analyzing the effect of economic growth in association with toxic emissions.

However, research conducted by other authors [41–45] assert the opposite, showing a negative relation between the emissions of CO_2 and financial development.

Tamazian et al. [41] argued that the level of CO_2 emissions illustrates the financial growth of each country, meaning that the fastest-growing economies have the largest energy consumption and therefore emit the most CO_2. The article claimed that financial development is the main factor in the increase of CO_2 discharge and overall pollution.

Shahbaz et al. [42], in the case of Malaysia and Indonesia, found that even though investments in the private sector helped lower the CO_2 emissions, foreign investments caused an increased in the release of this harmful gas. Chebbi et al. [43] presented how financial development negatively affects the level of pollution. Riaz's analysis in 2016 demonstrated that the increase in CO_2 emissions is directly proportional with financial development corresponding to a consumption rise. Even more, Abbasi and Riaz [44] associated the growth in the discharge of CO_2 with the economic blooming of the private sector. Jalil and Feridum [45] conducted a study which focused on China's case that appeared to have the same conclusion.

Yang et al. [46] affirm that studies regarding the evolution of the EKC only display the influence of financial growth upon pollution rather than focusing on the dynamic relationship between the two factors.

Lee and Chen [47] claimed that most EU countries, acknowledging the detrimental impact of the greenhouse effect on the planet, decided to invest in renewable energy to help reduce CO_2 emissions.

The empirical result of Shahbaz et al.'s [37] research in 2016 shows how economic growth, especially the development in the banking sector, has a positive effect on the reduction of CO_2 emissions. The authors suggest that opting for renewable energy should represent a priority for every advanced country's economy, because, as Halkos and Tzeremes [48] mentioned, by maximising energy efficiency the quality of the environment improves tremendously. In addition, these scholars propose that energy-efficient technology should be adjusted in regard to the production as well as at transportation and household levels so that productivity can be improved, and future generations can enjoy energetic power as previous generations have.

Nihal et al. [49] noted the difference between the rise of CO_2 emissions in relation with economic growth in developed countries as opposed to economic growth in developing nations while focusing on the Islamic Banking System.

Shah et al.'s [50] research confirmed the existence of the EKC and concluded that the dynamic between trade and the environment is still inconclusive depending on the strong institutional framework of each state after analysing 101 countries from 1995 to 2017.

Similarly, Jiang and Ma [51] concluded that in the case of developed countries there is no obvious relationship between financial development and carbon emission and urged policymakers to attentively calculate the effects of economic growth on the environment and find the best regulations that could offer stability between the two.

Technological progress is an important way to reduce carbon dioxide emissions [52]. The level of technological progress has been improved, low-carbon technologies have been developed and

energy use has been improved, thus reducing carbon dioxide emissions per unit of industrial added value. Second, with greater technological progress, more new products can be produced to replace energy-consuming inputs, thus reducing carbon dioxide emissions.

Therefore, the aim of this study is to examine the relationship between CO_2 emissions, energy use, economic growth, and financial development for 10 EU countries (Bulgaria, Czechia, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia, and Slovakia) over the 2000–2017 period. The paper has two objectives.

First, this paper emphasizes the importance of reducing the CO_2 emissions and takes financial developments into consideration to establish the long-run cointegration relationships among CO_2 emissions, energy use, GDP, and financial development, using the panel FMOLS and the cross-sectional dependence regression.

Second, in recent years, the problem of cross-sectional dependence of the data has been highlighted in many macroeconomic studies. Thus, the newly developed panel cross-sectional dependence regression is used in this study. To the best of our knowledge, such an analysis has not yet been performed at a European level to investigate the relationships between CO_2 emissions, energy use, economic growth and financial development.

3. Materials and Methods

According to World Population Review [53] "carbon dioxide emissions are greenhouse gases resulting from the burning of fossil fuels. While carbon dioxide is important in keeping the Earth a habitable temperature, the excessive CO_2 emissions caused by the increasing consumption of fossil fuels are disrupting Earth's carbon cycle and accelerating global warming".

At a global level, over the period 2010–2017, total global CO_2 emissions have increased from 33.1 Gt to 36.2 Gt [53] and are forecasted to rise in the upcoming years. Unfortunately, CO_2 emissions are increasing all over the world and the countries that are emitting the largest levels are not doing enough to diminish the emissions.

Broadly speaking, developed countries experience higher CO_2 emissions. China [53] has the highest level of CO_2 emissions, producing 904.07 million tons of carbon dioxide in 2015. The United States has the second-highest of 499.75 million tons and has the second-highest CO_2 emissions per capita of 15.53.

According to data provided by Eurostat [54], in 2018, 620 million tonnes less of CO_2 equivalents were emitted. Among the EU Member States, the CO_2 emissions coming from different producers and households fluctuated deeply. These differences are, partially, because of different economic structures and diverse mixtures of renewable and non-renewable energy sources.

Particularly, as stated by the European Environment Agency [55], between 1990 and 2018, CO_2 emissions fell by 69.4% in the EU. Between 2017 and 2018, the decrease was 4.3%, mainly because emissions fell in Italy, France, Germany, and Hungary (countries ranked according to the size of their contribution to the absolute change). In 2018, the EU Member States contributing most (i.e., more than 10%) to CO_2 emissions were Germany, France, Poland, and Italy (countries ranked according to their shares of the EU total). Belgium explained that the peak of CO_2 emissions in 2013 was because one of its plants produced lime without oxygen. Romania reported a significant increase in CO_2 emissions from 2004 to 2005, reflected mainly by data for the category 'Road transport: Passenger cars'.

Moreover, according to International Energy Agency (IEA), [56] "across Europe emissions fell by 1.3%, or 50 Mt. The emissions decline was driven by a drop of 4.5% in Germany, as both oil and coal combustion fell sharply. The drop in coal consumption was concentrated in the power sector, where generation from renewables reached a record high of 37% of the electricity mix. Electricity generation from renewables also saw a record year in the United Kingdom, accounting for 35% of generation, as the share of coal fell to 5%, a record low". As a result, CO_2 emissions in the United Kingdom declined for a sixth year, hitting some of the lowest levels recorded since 1888. France also

saw a significant drop in emissions, as electricity generation from hydroelectric and nuclear power stations meant that coal and gas plants saw lower utilisation in 2018 than in 2017.

In another train of thought, hydrogen has long been regarded as an energy carrier of the future. It is also discussed as the foundation of a sustainable hydrogen economy. There are also different ways of supplying hydrogen. Today, hydrogen is obtained mainly by steam reforming natural gas. In the medium term, a growing proportion of biogas from municipal waste is expected to reach 10% by 2030 and fall again to 0% in 2050 [57]. In the longer term, hydrogen generation by electrolysis on the basis of renewable surplus electricity is gaining ground, reaching 100% by 2050, to allow greenhouse gas emissions to decrease by 80% compared to 1990. The calculation of the greenhouse gas emission factors of the hydrogen mixture over time is based on the emission factors for individual supply routes.

Nevertheless, hydrogen is produced by several means, including water electrolysis, in which water molecules are divided into hydrogen and oxygen molecules [58]. The low-capacity, low-cost electrolysis system is a key technology that can support greater use of zero-carbon hydrogen for a variety of applications and is a technology that can facilitate the integration of larger renewable energy sources. The price of electricity and the cost of capital of the electrolyser are the most important factors that determine the cost of hydrogen production in the process of electrolysis of water, so any reduction in the cost of the electrolyser will be reflected in lowering the cost of hydrogen generation.

However, concerning the long-term targets of climate change policies to achieve, the EU countries seem not to be so ambitious. Thus, according to the report of Climate Action Network Europe [54], the rankings that assess both the role that the Member States have in setting ambitious climate and energy targets, show that no EU countries managed to fulfil the target. Thus, they are failing to enhance their climate action according to the Paris Agreement objective. None of the EU countries had accomplished enough in both ambition and progress in mitigating carbon emissions.

Furthermore, in recent years, natural gas has received increasing attention in the context of climate change mitigation. Described as "bridge fuel", it is seen as helping in the process of transforming low-carbon energy. Most experts have concluded that natural gas is a bridge to a low-carbon economy, as it produces much less CO_2 when burned than coal or oil [59]. At the same time, the use of gas comes to complement the fluctuating supply of energy from renewable sources, because modern gas-fired power plants (as opposed to coal-fired ones) can reach full power in a few minutes, if necessary.

Even the German government has estimated that planned exit from nuclear and coal-fired power generation will increase the country's dependence on natural gas in the medium term. Most customers in Germany (80%) choose natural gas if they decide to change energy sources when renewing their gas system heating. Since 2009, natural gas heating has replaced oil-based systems in about 275,000 buildings, while only 17,000 buildings have switched from oil to district heating. To stimulate this shift to environmentally friendly heating, the government has promised a 20% reduction in the cost of changing the heating system by reducing the tax [60].

However, a number of studies [61,62] have concluded that when methane emissions released during the production and transport of natural gas are taken into account, natural gas is no better than environmental coal. If all emissions are taken into account, natural gas could actually be worse. Technologies are available to reduce much of the methane leakage, but deploying such technology would require new policies and investments.

One solution to this problem would be to use the country's gas infrastructure to transport energy in the form of green gas, which would make a valuable contribution to decarbonisation in the future. It is considered unrealistic to imagine that Germany will be able to rely on the intermittent supply of solar and wind energy without continuing to use the expanded storage capacity of its gas network. The use of both the gas storage network and the gas transmission networks will be cheaper than the alternative for electricity.

The federal government is betting heavily on green hydrogen in search of climate neutrality although currently power-to-gas as a way of converting electrical energy into methane or hydrogen for direct use or the long-term storage of renewable power has only been tested in pilot projects [63].

Related to the group of Central and Eastern European countries analysed in this study, Estonia and Slovenia are advised to take action and to promote more ambitious climate and energy policies and targets, both at national and at EU levels. Furthermore, most Central and Eastern European countries are not making important steps when it comes to climate policies. Some of these countries have high scores in the rankings [64] (Lithuania, on 10th place and Latvia on 12th place), because of low climate and energy targets received due to their low average income. Furthermore, they often have low energy consumption and greenhouse gas emission numbers due to their economic situation. Slovenia and the Czech Republic [64] can be considered more advanced from this point of view. Estonia (27th place) and Poland (29th place) [64] rank lowest due to their disapproval of climate action both at country and at EU levels.

The research aims to analyse the relationship between CO_2 emissions, energy use, economic growth and financial development for 10 Central and Eastern European countries (CEEC) over the 2000–2017 period in order to identify the most suitable solutions to reduce CO_2 emissions in these countries and generate positive effects on the environment without affecting the economic growth and the financial development.

For the relationship to be analysed, the following variables are considered to be the most representative: CO_2 emissions, energy use, gross domestic product, squared gross domestic product and financial development. The annual data used in the paper were collected from the World Development Indicators and Eurostat. Energy consumption (EC) is measured in kg of oil equivalent per capita. Economic growth is represented by the rise in real Gross Domestic Product (GDP) per capita, and bank deposits to GDP are used to measure financial development (BD).

From the analysis perspective, it starts from the applicability of the EKC Theory [65] that analyses the relationship between environmental performance and economic growth.

Examining the equation proposed by He et al. [66] in their study, the following equation was developed in order to determine the relationship between the above-mentioned variables, which was not analysed before in case of the panel of ten analysed CEEC:

$$\ln CO_{2t} = \beta_1 + \beta_2 \ln EC_t + \beta_3 \ln GDP_t + \beta_4 \ln GDP^2_t + \beta_5 \ln BD_t + \mu_t \tag{1}$$

where $\ln CO_2$ is the natural logarithm of carbon-dioxide emissions, $\ln EC$ is the natural logarithm of the energy use, $\ln GDP$ is the natural logarithm of real gross domestic product per capita, $\ln GDP^2$ is square of the natural logarithm of real gross domestic product per capita, $\ln BD$ is the natural logarithm of bank deposits to GDP, $\beta_{(1,\ldots,5)}$ are coefficients associated to the variables, μ_t is the residual term and t is the time period.

According to the EKC hypothesis and Equation (1), multiple existing relationships between the CO_2 emissions and the economic growth can be identified, depending on the values of the coefficients β associated with the variables. For example, if $\beta_3 \geq 0$ and $\beta_4 \leq 0$ this indicates that initially, the economic growth generates an increase of CO_2 emissions, but this will decrease when the economy reaches maturity. The same is available for energy use, a positive value of β_2 will generate an increase of CO_2 emissions.

The innovation brought by this methodology consists of using a data panel of 10 countries, unlike the other authors [35,36,39,40,43,54] who chose to perform the analysis only for one country. Moreover, using the data panel enables us to obtain more reliable results given that performing a country by country analysis may lead to erroneous results. Furthermore, this panel data methodology is used for applying later on the Vector Error Correction Model (VECM) method as this method is suitable for data series with a low number of observations.

The first step taken in analyzing the causal relationship between the variables included in a model is to test the stationarity of the data series used. This test is performed using panel root tests specific to panel data. In the present study, it was decided to use the test proposed by Levin-Lin-Chu [67] which involves a common unit root process, so that this test does not allow the possibility that data provided for a variable in a particular country included in the panel to be stationary and for another country to

have unitary root. The null hypothesis of this test is that the data series contains the unit root, and the alternative hypothesis assumes that the series is stationary. The Levin-Lin-Chu test with panel-specific means requires that the number of time periods grows more quickly than the number of panels, so the ratio of panels to time periods tends to zero, which makes this test appropriate for the proposed model.

The second stage involves the application of co-integration tests to verify the existence of a co-integration relationship between the variables included in the analysis. Two cointegration tests based on the Engle-Granger two-step [68] specific to panel data were used for this purpose: the Pedroni test [69,70] and the Fisher test [71]. The Engle-Granger co-integration test is based on an examination of the residuals of an erroneous regression performed using I (1) variables. If the variables are co-integrated then the residuals should be I (0). On the other hand, if the variables are not co-integrated then the residuals will be I (1). Pedroni [69,70] and Fisher [71] extend the Engle-Granger framework to tests involving panel data.

After having established the long-run co-integration relationship in the CO_2 emission model, in the next part of the analysis, Fully Modified Ordinary Least Squares (FMOLS) is used in order to examine the elasticity of CO_2 emissions to energy use, economic growth and financial development. Thus, Phillips and Hansen [72] suggest an estimator which uses a semi-parametric correction to remove the difficulties entailed by the long-run correlation between the co-integrating equation and stochastic regressors innovations. As the panel estimation can be broadly divided into four models of fixed, random effects, as well as the pooling model and mean group. The difference is a model for the number of restriction conditions. The pooling model assumes that the individual intercept and coefficient have homogeneous qualities, whereas the random effect and fixed effects model relaxes the assumption of the pooling model that allows each individual intercept to be heterogeneous.

Pedroni [73] describes feasible pooled FMOLS estimators for heterogeneous co-integrated panels where the long-run variances differ across cross-sections:

- Pooled estimation performs standard FMOLS on the pooled sample after removing the deterministic components from both the dependent variable and the regressors.
- Pooled (weighted) estimation accounts for heterogeneity by using cross-section specific estimates of the long-run covariance to reweight the data prior to computing pooled FMOLS.
- Grouped mean estimation computes the cross-section average of the individual cross-section FMOLS estimates.

If the variables are co-integrated, a Vector Error Correction Model (VECM) is used to identify short-term and long-term causal relationships. This model is a restricted VAR designed for use with nonstationary series which are known to be co-integrated. The VECM indicates co-integration relationships embedded in the specifications so as to restrict the long run conduct of the endogenous variables in order to converge to their co-integrating relationships while allowing for short-run adjustment dynamics. The co-integration term is also known as the error correction term (ECT) because the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. The estimated values of the error correction term reveal the speed of adjustment from short-run to long-run equilibrium in the models depending on the sign of the corresponding coefficient. The equations in the model of this study can be expressed as a system of equations as follows:

$$
\begin{bmatrix}
\Delta \ln CO_{2it} \\
\Delta \ln EC_{it} \\
\Delta \ln GDP_{it} \\
\Delta \ln GDP_{it}^2 \\
\Delta \ln BD_{it}
\end{bmatrix}
=
\begin{bmatrix}
\rho_1 \\
\rho_2 \\
\rho_3 \\
\rho_4 \\
\rho_5
\end{bmatrix}
+ \sum_{p=1}^{q}
\begin{bmatrix}
\delta_{11,p} \delta_{12,p} \delta_{13,p} \delta_{14,p} \\
\delta_{21,p} \delta_{22,p} \delta_{23,p} \delta_{24,p} \\
\delta_{31,p} \delta_{32,p} \delta_{33,p} \delta_{34,p} \\
\delta_{41,p} \delta_{42,p} \delta_{43,p} \delta_{44,p} \\
\delta_{51,p} \delta_{52,p} \delta_{53,p} \delta_{54,p}
\end{bmatrix}
\begin{bmatrix}
\Delta \ln CO_{2it-1} \\
\Delta \ln EC_{it-1} \\
\Delta \ln GDP_{it-1} \\
\Delta \ln GDP_{it-1}^2 \\
\Delta \ln BD_{it-1}
\end{bmatrix}
+
\begin{bmatrix}
\varphi_1 \\
\varphi_2 \\
\varphi_3 \\
\varphi_4 \\
\varphi_5
\end{bmatrix}
ECT_{it-1} +
\begin{bmatrix}
\mu_{1,it} \\
\mu_{2,it} \\
\mu_{3,it} \\
\mu_{4,it} \\
\mu_{5,it}
\end{bmatrix}
\quad (2)
$$

where Δ is the first difference operator, t is the time period from 2000 to 2017, i represents the cross-sections and $\mu_{i,t}$ are the serially independent random errors. In general, the ECT_{it-1} should be negative and between 0–1.

After confirming the short- and long-run relationship between the variables in the model, the Granger causality can be applied to investigate the direction of causality among the variables.

4. Empirical Results and Discussions

Global warming potential (GWP) refers to the contribution of different gases to global warming relative to that of carbon dioxide over a period of 100 years [74]. Given the importance of carbon dioxide emissions, it was considered necessary to insert this variable in the developed model similar to other studies that emphasize the importance of CO_2 emissions [75–78].

To show the correlation coefficients between variables, a correlation matrix is used. Each cell in the table shows the correlation between the two variables. A correlation matrix is used to summarize data, as input into a more advanced analysis, and as a diagnostic for advanced analyses (see Table 1).

Table 1. Correlation matrix for the variables in ten Central and Eastern European countries (CEEC).

	$\ln CO_2$	$\ln EC$	$\ln GDP$	$\ln GDP^2$	$\ln BD$
$\ln CO_2$	1.000000 -				
$\ln EC$	−0.212269 (0.0042)	1.000000 -			
$\ln GDP$	−0.161711 (0.0301)	0.669684 (0.0000)	1.000000 -		
$\ln GDP^2$	−0.162508 (0.0293)	0.660865 (0.0000)	0.999628 (0.0000)	1.000000 -	
$\ln BD$	0.174975 (0.0188)	0.267564 (0.0003)	0.628346 (0.0000)	0.628279 (0.0000)	1.000000 -

Note: $\ln CO_2$ is the natural logarithm of CO_2 emissions, $\ln EC$ is the natural logarithm of the energy use, $\ln GDP$ is the natural logarithm of real gross domestic product per capita, $\ln GDP^2$ is square of the natural logarithm of real gross domestic product per capita, $\ln BD$ is the natural logarithm of bank deposits to GDP.

The result of the correlation matrix indicates that there is a negative correlation between model variables, but this is less intense in the case of CO_2 emissions from real GDP per capita and bank-deposits to GDP, compared to that between real GDP per capita and bank-deposits to GDP and that between energy consumption and real GDP per capita.

The results of the LLC unit root test indicate that all variables are stationary at level or first difference. So, for all variables, the null hypothesis of unit root is rejected after the first difference, and it is accepted the alternative hypothesis of no unit root (see Table 2).

Table 2. Levin-Lin-Chu (LLC) unit root test at a base level and first difference for the variables in ten CEEC.

	Methods	Common Unit Root Process LLC
$\ln CO_2$	Statistic (*p*)	−0.61755 (*0.2684*)
$d\ln CO_2$	Statistic (*p*)	−7.76323 (*0.0000*)
$\ln EC$	Statistic (*p*)	−3.04150 (*0.0012*)
$d\ln EC$	Statistic (*p*)	−4.34066 (*0.0000*)
$\ln GDP$	Statistic (*p*)	−2.50821 (*0.0061*)
$d\ln GDP$	Statistic (*p*)	−5.99727 (*0.0000*)
$\ln GDP^2$	Statistic (*p*)	−2.28010 (*0.0113*)
$d\ln GDP^2$	Statistic (*p*)	−6.09535 (*0.0000*)
$\ln BD$	Statistic (*p*)	−2.87963 (*0.0020*)
$d\ln BD$	Statistic (*p*)	−5.36287 (*0.0000*)

Note: $\ln CO_2$ is the natural logarithm of CO_2 emissions, $\ln EC$ is the natural logarithm of the energy use, $\ln GDP$ is the natural logarithm of real gross domestic product per capita, $\ln GDP^2$ is square of the natural logarithm of real gross domestic product per capita, $\ln BD$ is the natural logarithm of bank deposits to GDP, LLC is Levin-Lin-Chu test, *p* is *p*-value.

Given that all variables are stationary at the first difference, the necessary co-integration tests were further performed to verify whether there is a long-term co-integrating relationship between the model variables. Co-integration test should be performed on the level form of the variables and not on their first difference. The first co-integration test used is the Pedroni test.

Pedroni is one of the most important and widely used tests of cointegration for panel data. Pedroni [69,70] proposes several tests for cointegration that allow for heterogeneous intercepts and trend coefficients across cross-sections. The first four statistics are within-dimension based statistics and the rest are between-dimension based statistics. In his paper, Pedroni [69] describes the seven test statistics, "The first of the simple panel cointegration statistics is a type of non-parametric variance ratio statistics. The second is a panel version of a non-parametric statistics that is analogous to the familiar Phillips Perron rho-statistics. The third statistics is also non-parametric and is analogous to the Phillips and Perron t-Statistics. The fourth statistics is the simple panel cointegration statistics which is corresponding to augmented Dickey-Fuller t-statistics." [69]. "The rest of the statistics are based on a group mean approach. The first of these is analogous to the Phillips and Perron rho-statistics, and the last two analogous to the Phillips and Perron t-statistics and the augmented Dickey-Fuller t-statistics respectively." [69].

The test results presented in Table 3 show that, in the within-dimension part, four of the eight statistical tests reject the null hypothesis, while in the between-dimension part, two of the three statistical tests accept the alternative hypothesis. This indicates the existence of a long-term coin-integration relationship between model variables.

Table 3. Pedroni co-integration test for the variables in ten CEEC.

Alternative Hypothesis: Common AR coefs. (within-dimension)				
	Statistic	Prob.	Statistic	Prob.
Panel v-Statistic	0.196313	0.4222	−0.386333	0.6504
Panel rho-Statistic	3.247227	0.9994	3.123919	0.9991
Panel PP-Statistic	−6.931241	0.0000	−8.431888	0.0000
Panel ADF-Statistic	−7.148236	0.0000	−7.733481	0.0000
Alternative Hypothesis: Individual AR coefs. (between-dimension)				
	Statistic	Prob.		
Group rho-Statistic	4.434589	1.0000		
Group PP-Statistic	−11.21615	0.0000		
Group ADF-Statistic	−6.270727	0.0000		

Note: v-Statistic is non-parametric variance ratio statistics, rho-Statistic is panel version of a non-parametric statistics that is analogous to the familiar Phillips Perron rho-statistics, PP-Statistic is Phillips and Perron test, ADF is Augmented Dickey-Fuller test.

Taking into account that not all the results included in the Pedroni test indicate the existence of a co-integration relationship between the model variables, in order to ensure the accuracy of the analysis, the Fisher cointegration test was additionally performed.

Fisher's cointegration test combines individual cross-sections. This method uses two ratio tests such as a trace test and maximum eigenvalue (max-eigen) test. This panel cointegration test may be robust than the conventional co-integration tests based on the Engle-Granger two-step approach (see Table 4).

Fisher [71] derives a combined test that uses the results of the individual independent tests. Maddala and Wu [79] use Fisher's result in order to propose another approach to test the co-integration in panel data by combining tests from individual cross-sections in order to achieve a test statistic for the full panel. The test also shows that the null hypothesis of no co-integration is rejected and the *p*-value (0.0000) gives strong evidence that the variables have a long-run relationship.

Table 4. Fisher co-integration test for the variables in ten CEEC.

Hypothesized	Fisher Stat.		Fisher Stat.	
No. of CE(s)	(from trace test)	Prob.	(from max-eigen test)	Prob.
None	427.7	0.0000	289.8	0.0000
At most 1	252.8	0.0000	174.6	0.0000
At most 2	112.6	0.0000	82.40	0.0000
At most 3	51.98	0.0001	49.33	0.0003
At most 4	27.18	0.1301	27.18	0.1301

As at least one cointegration relationship is found between the model variables, the long-term cointegration coefficients will be determined using FMOLS to examine the elasticity of CO_2 emissions to energy use, economic growth and financial development and present the results in Table 5.

Table 5. Panel Fully Modified Ordinary Least Squares (FMOLS) Estimation for the variables in ten CEEC.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
lnEC	0.653606	0.062478	10.46132	0.0000
lnGDP	0.164444	0.030477	5.395629	0.0000
lnGDP^2	−0.068040	0.040956	−1.661279	0.0987
lnBD	−0.287253	0.029633	−9.693786	0.0000

Note: lnCO_2 is the natural logarithm of CO_2 emissions, lnEC is the natural logarithm of the energy use, lnGDP is the natural logarithm of real gross domestic product per capita, lnGDP^2 is square of natural logarithm of real gross domestic product per capita, lnBD is the natural logarithm of bank deposits to GDP.

However, the multicollinearity of the variables should be tested in order for the results of the FMOLS regression to be valid and to verify if the independent variables are not correlated among them. This can be accomplished by using the Variance Influence Factor (VIF) from Eviews, so that no multicollinearity exists, the VIF values must be below 10. Table 6 shows that the independent variables are not correlated between them, the obtained VIF values being very low.

Table 6. Variance Inflation Factors.

	Coefficient	Uncentered
Variable	Variance	VIF
lnEC	0.003904	1.150130
lnGDP	0.000929	4.705460
lnGDP^2	0.001677	1.086604
lnBD	0.000878	5.047029

This study uses the weighted pooled FMOLS estimator as this estimation accounts for heterogeneity by using cross-section specific estimates of the long run covariances to reweight the data prior to computing pooled FMOLS. The results show that energy use, economic growth expressed by GDP, and financial development are statistically significant at the 5% level for the panel FMOLS and economic growth expressed by GDP^2 is statistically significant at a 10% level. Firstly, the long-run elasticity of CO_2 emissions to energy use is 0.65, indicating that a 1% decrease in energy use leads to a 0.73% decrease in CO_2 emissions. Secondly, the long-run elasticity of CO_2 emissions to economic growth is 0.16 and −0.06, respectively, indicating that a 1% decrease in economic growth leads to 0.16% decrease and then after the turning point to 0.06 increase in CO_2 emissions. Thirdly, the long-run elasticity of CO_2 emissions to financial development is −0.28, indicating that a 1% decrease in financial development leads to a 0.28% increase in CO_2 emissions.

Thus, turning to the EKC theory, the results (see Table 5) indicate evidence of an inverted U-shaped relationship between CO_2 emissions and economic growth because the coefficient associated to the

linear term GDP per capita is positive and that associated to the nonlinear term (GDP^2) is negative. This result supports EKC Theory [32] for the ten CEEC over the 2000–2017 period according to which CO_2 emissions increase within the first phase of the economic growth and decrease after reaching a certain threshold. Therefore, an increase with 1% of GDP will generate in the long run, within the first phase, an increase with 0.16% of CO_2 emissions, followed by a decrease with 0.06%.

The existence of a cointegration relationship between the variables of the model implies the existence of a causality relationship at least from one direction. To determine the causality relationship between CO_2 emissions, energy use, economic growth and financial development, the Granger test based on VECM framework was used (see Table 7).

Table 7. Vector Error Correction Model (VECM) estimation for the variables in ten CEEC.

Error Correction:	d(lnCO_2)	d(lnEC)	d(lnGDP)	d(lnGDP^2)	d(lnBD)
ECT(−1)	0.000196	0.000183	2.74E−05	−0.000272	0.000292
	(0.00026)	(0.00022)	(0.00017)	(0.00312)	(0.00021)
	[0.74396]	[0.81266]	[0.16213]	[−0.08724]	[1.42057]
d(lnCO_2(−1))	−0.124190	−0.102123	0.091125	1.605381	−0.170121
	(0.09147)	(0.07806)	(0.05863)	(1.08278)	(0.07146)
	[−1.35778]	[−1.30828]	[1.55417]	[1.48264]	[−2.38063]
d(lnEC(−1))	0.001756	−0.131176	−0.064122	−1.166500	0.042640
	(0.09049)	(0.07722)	(0.05800)	(1.07118)	(0.07070)
	[0.01941]	[−1.69867]	[−1.10547]	[−1.08898]	[0.60316]
d(lnGDP(−1))	−4.332138	−0.113608	2.439813	40.32668	1.445159
	(3.40651)	(2.90721)	(2.18370)	(40.3270)	(2.66146)
	[−1.27172]	[−0.03908]	[1.11729]	[0.99999]	[0.54299]
d(lnGDP^2(−1))	0.237237	0.009988	−0.114057	−1.847848	−0.055613
	(0.18613)	(0.15885)	(0.11931)	(2.20341)	(0.14542)
	[1.27460]	[0.06288]	[−0.95594]	[−0.83863]	[−0.38243]
d(lnBD(−1))	0.310493	0.176554	0.140718	2.533298	0.366370
	(0.09444)	(0.08060)	(0.06054)	(1.11804)	(0.07379)
	[3.28760]	[2.19047]	[2.32431]	[2.26583]	[4.96520]
C	−0.014303	−0.006045	0.017455	0.314582	0.001730
	(0.00845)	(0.00721)	(0.00542)	(0.10006)	(0.00660)
	[−1.69223]	[−0.83798]	[3.22172]	[3.14404]	[0.26197]

Note: lnCO_2 is the natural logarithm of CO_2 emissions, lnEC is the natural logarithm of the energy use, lnGDP is the natural logarithm of real gross domestic product per capita, lnGDP2 is square of the natural logarithm of real gross domestic product per capita, lnBD is the natural logarithm of bank deposits to GDP, *VECM* is Vector Error Correction Model, *ECT* is lagged error correction term.

This test shows if there is a short-run, long-run, or strong causality between the variables. To explain the long-run causality effects, the t-statistics of the ECT are analyzed. If the value of t-statistics is negative then there is a long-run relationship among variables. Regarding the existence of a short-term relationship between variables, this is given by the *p*-value assigned to the coefficients associated with each variable. Thus, if the *p*-value is less than 0.5, then the null hypothesis of lack of co-integration is rejected and the alternative hypothesis of the existence of a short-term causality relationship between the model variables is accepted.

These results of the short-run relationships from the VECM estimation are described through the corresponding equations presented below (see also Table 8 with the probabilities of the corresponding coefficients).

$$d(\ln CO_2) = C(1)*(\ln CO_2(-1) + 12.08*\ln EC(-1) - 1182.05011967*\ln GDP(-1) +$$
$$61.86*\ln GDP2(-1) - 29.63*\ln BD(-1) + 5650.68) + C(2)*d(\ln CO_2(-1)) + \quad (3)$$
$$C(3)*d(\ln EC(-1)) + C(4)*d(\ln GDP(-1)) + C(5)*d(\ln GDP2(-1)) + C(6)*d(\ln BD(-1)) + C(7)$$

$$d(\ln EC) = C(8)*(\ln CO_2(-1) + 12.08*\ln EC(-1) - 1182.05*\ln GDP(-1) + 61.86*\ln GDP2(-1) -$$
$$29.63*\ln BD(-1) + 5650.68) + C(9)*d(\ln CO_2(-1)) + C(10)*d(\ln EC(-1)) + C(11)*d(\ln GDP(-1)) + \quad (4)$$
$$C(12)*d(\ln GDP2(-1)) + C(13)*d(\ln BD(-1)) + C(14)$$

$$d(\ln GDP) = C(15)*(\ln CO_2(-1) + 12.08*\ln EC(-1) - 1182.05*\ln GDP(-1) + 61.86*\ln GDP2(-1) -$$
$$29.63*\ln BD(-1) + 5650.68) + C(16)*d(\ln CO_2(-1)) + C(17)*d(\ln EC(-1)) + C(18)*d(\ln GDP(-1)) \quad (5)$$
$$+ C(19)*d(\ln GDP2(-1)) + C(20)*d(\ln BD(-1)) + C(21)$$

$$d(\ln GDP2) = C(22)*(\ln CO_2(-1) + 12.08*\ln EC(-1) - 1182.05*\ln GDP(-1) + 61.86*\ln GDP2(-1)$$
$$- 29.63*\ln BD(-1) + 5650.68) + C(23)*d(\ln CO2(-1)) + C(24)*d(\ln EC(-1)) + \quad (6)$$
$$C(25)*d(\ln GDP(-1)) + C(26)*d(\ln GDP2(-1)) + C(27)*d(\ln BD(-1)) + C(28)$$

$$d(\ln BD) = C(29)*(\ln CO_2(-1) + 12.08*\ln EC(-1) - 1182.05*\ln GDP(-1) + 61.86*\ln GDP2(-1) -$$
$$29.63*\ln BD(-1) + 5650.68) + C(30)*d(\ln CO_2(-1)) + C(31)*d(\ln EC(-1)) + C(32)*d(\ln GDP(-1)) +$$
$$C(33)*d(\ln GDP2(-1)) + C(34)*d(\ln BD(-1)) + C(35)$$

$$(7)$$

Table 8. Coefficients of the short-run equations from the VECM estimation.

	Coefficient	Prob.		Coefficient	Prob.
C(1)	0.000196	0.4571	C(18)	2.439813	0.2642
C(2)	−0.124190	0.1749	C(19)	−0.114057	0.3394
C(3)	0.001756	0.9845	C(20)	0.140718	0.0204
C(4)	−4.332138	0.2039	C(21)	0.017455	0.0013
C(5)	0.237237	0.2028	C(22)	−0.000272	0.9305
C(6)	0.310493	0.0011	C(23)	1.605381	0.1386
C(7)	−0.014303	0.0910	C(24)	−1.166500	0.2765
C(8)	0.000183	0.4167	C(25)	40.32668	0.3176
C(9)	−0.102123	0.1912	C(26)	−1.847848	0.4019
C(10)	−0.131176	0.0898	C(27)	2.533298	0.0237
C(11)	−0.113608	0.9688	C(28)	0.314582	0.0017
C(12)	0.009988	0.9499	C(29)	0.000292	0.1558
C(13)	0.176554	0.0288	C(30)	−0.170121	0.0175
C(14)	−0.006045	0.4023	C(31)	0.042640	0.5466
C(15)	2.74E−05	0.8712	C(32)	1.445159	0.5873
C(16)	0.091125	0.1206	C(33)	−0.055613	0.7022
C(17)	−0.064122	0.2693	C(34)	0.366370	0.0000
			C(35)	0.001730	0.7934

The results previously processed for the ten countries were connected with the results achieved by applying Pairwise Granger causality tests to detect the direction of causality on the long-run and short-run relationship between CO_2 emissions, energy use, economic growth and financial development. These results were summarized in the figure below.

According to the results obtained in Figure 1, the direction of causality on the long run is from financial development (BD) to carbon oxide emissions (CO_2), energy use (EC) and economic growth (GDP) and from GDP and GDP^2 to financial development (BD). This means that, in the long run, the levels of CO_2 emissions and energy use do not have any influence on economic growth (GDP and GDP^2). Also, there is a bidirectional causality among GDP and BD variables in the long run. Thus, increasing financial development will generate more CO_2 emissions and more energy use and increasing economic growth will lead to rising financial development.
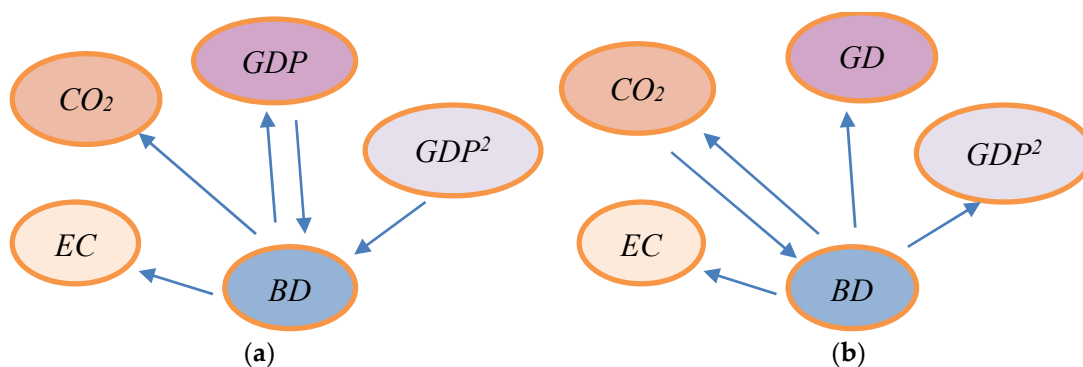
Figure 1. Summary of Granger causality relationships in ten CEEC. (**a**) Long-run relationships (**b**) Short-run relationships.

However, in the short run, things change and the direction of causality is from financial development variable to all the other variables in the model. Thus, on a short run, increasing financial development will generate more CO_2 emissions and will lead to increased energy use and economic growth. Also, a bidirectional causality is being revealed between financial development and CO_2 emissions. This indicates that financial development may help to reduce CO_2 emissions.

The results above prove that financial development has a significant influence on the level of CO_2 emissions, energy use, and economic growth both on a long and short run in the ten CEEC. Nevertheless, on a short run, the influence of financial development on the energy use was identified meaning that for the countries with a high level of pollution the level of financial development is important when they aim for results on a long run, but at the same time, they have to focus on other measures on a short run in order to reduce the negative impact that the high level of energy use has on the climate changes.

In terms of individual countries (see Table 9), energy use was found to be statistically significant except in the cases of Czechia and Estonia. Moreover, the elasticity of energy use to CO_2 emissions is found to be negative in Bulgaria, Latvia, Lithuania, and Slovenia. It is worth noting that Lithuania and Latvia scored highly in climate change target ranking compared to the other analysed CEEC [64] because of the very low climate and energy targets received due to their low average income. This is irrespective of their potential and because of the low energy consumption and greenhouse gas emission numbers relating to their economic situation. Nevertheless, Slovenia [64] can be considered more advanced from this point of view. Therefore, energy consumption plays an important role in the ten CEEC in terms of explaining CO_2 emissions.

Turning to the long-run relationships between CO_2 emissions and economic growth for the individual ten CEEC, six countries exhibit an inverted U-shaped pattern, but the coefficients were not statistically significant. Thus, GDP is still one of the possible causes of CO_2 emissions for some of the analysed countries. Beyond doubt, CO_2 emissions generated by fossil fuels are still the majority.

Furthermore, the results also reveal that the coefficient of financial development for the CO_2 emissions is negative and statistically significant for all countries except for Hungary, Romania, and Slovenia. Thus, a policy that supports financial development can help those countries to adjust the amount of their CO_2 emissions.

Table 9. Cross-sectional dependence estimation for the variables in ten CEEC.

Country	Variable	Coefficient	*p*-Value
Bulgaria	EC	−0.263088	0.0044
	GDP	−72.24563	0.8834
	GDP^2	4.366759	0.0686
	BD	−0.557293	0.0049
Czechia	EC	0.003082	0.5765
	GDP	12.17861	0.9719
	GDP^2	−0.624481	0.524
	BD	−0.363407	0.0001
Estonia	EC	0.073565	0.6053
	GDP	24.2973	0.9575
	GDP^2	−1.283788	0.3617
	BD	−1.043159	0.0003
Latvia	EC	−0.32438	0.0000
	GDP	39.23274	0.8546
	GDP^2	−2.175763	0.0359
	BD	−0.770434	0.0000
Lithuania	EC	−0.052222	0.0434
	GDP	−19.45662	0.6592
	GDP^2	1.087511	0.0028
	BD	−0.148186	0.0002
Hungary	EC	0.158425	0.0001
	GDP	14.57053	0.9908
	GDP^2	−0.703012	0.8497
	BD	0.932624	0.0024
Poland	EC	0.372734	0.0000
	GDP	8.322376	0.9475
	GDP^2	−0.386933	0.3514
	BD	−0.298264	0.0001
Romania	EC	0.269810	0.0019
	GDP	−13.8362	0.9089
	GDP^2	0.867857	0.0993
	BD	0.179199	0.0052
Slovenia	EC	−0.218205	0.0018
	GDP	−122.7256	0.9610
	GDP^2	6.233204	0.3737
	BD	0.00039	0.9862
Slovakia	EC	0.257372	0.0001
	GDP	20.03534	0.9295
	GDP^2	−1.028643	0.1786
	BD	−0.001263	0.9408

5. Conclusions

This study has implemented the panel unit root, co-integration, FMOLS, cross-section dependence regressions, and VECM model in order to test for the long- and short-run relationships and to prevent any erroneous regression among CO_2 emissions, energy use, economic growth, and financial development.

The panel FMOLS and cross-section dependence regression were applied and statistically significant at the 5% and 10% level over the 2000–2017 period. Thus, there are likely to be efficient methods for reducing CO_2 emissions through the technological progress of energy use.

The novelty of this research is given by the fact that most of the studies related to the nexus between CO_2 emissions, energy use, economic growth and financial development are performed by

researchers from outside the EU and investigations are made mostly in the OECD countries with specifics not related to EU countries. Furthermore, the selection of this range of CEEC is innovative as most of the countries have some features in common: they are countries from the Eastern and Central Europe and also ex-communist and emerging countries from EU, the last 10 to join so far. Furthermore, these countries had to adapt quickly to the EU policies on environmental protection despite a lower financial development level as against the Western more developed economies. Additionally, choosing the variable bank-deposits to GDP for measuring the financial development can be considered another innovation as this is a relevant financial variable.

Furthermore, the coefficient of financial development in CO_2 emissions is negative and statistically significant. This finding emphasizes and recommends the fact that the ten CEEC have to take action rapidly in reducing the negative impact of CO_2 emissions on the environment. However, EU is also increasingly active in making efforts to reduce greenhouse gases, including cutting CO_2 emissions to help the EU countries avoid the effects of fluctuations in energy prices and to promote a more competitive energy market. Nevertheless, the EU is also promoting technological innovation while also attempting to increase the number of job opportunities. Thus, our recommendation is that a policy that stimulates financial development can help countries to adjust the amount of their CO_2 emissions.

However, the long-run economic growth elasticity of CO_2 emissions supports the existence of the EKC theory only for the panel of CEEC over the 2000–2017 period. In terms of long-run relationships between CO_2 emissions and economic growth for individual CEEC, the EKC theory is supported only for six countries but the coefficients of the variables are not statistically significant.

The causality tests reveal significant findings. These results indicate and recommend the fact that by using environment-friendly policies, the national economy in the long run or short run will not be compromised, and so the government can implement green policies to control energy demand in order to reduce energy use. Concerning the reduction of CO_2 emissions, results show that financial development and CO_2 emissions have a bidirectional relationship and thus the government can implement a lower energy emission factor during the process of financial development, such as an increase in the use of renewables, a switch from coal to gas for power generation. In comparison with that generated from fossil fuels, electricity generated from renewable energy sources gives rise to lower greenhouse gas emissions and, implicitly, to CO_2 emissions.

Unlike other regions, as has been stated in the first part of this study, EU countries are the most committed to the development of renewable energy and to reduce their carbon dioxide emissions. As the President of ECB, herself stated, "substantial investment is likely to be required to underpin the energy transition, with some estimates running to hundreds of billions of euro each year in the European Union alone" [80]. According to the European Commission [81], "achieving the Paris Agreement targets requires up to €260 billion of additional investment per year".

However, while most countries are not doing enough to bridge the "emission gap" [9], there is huge potential to curb emissions at local, city and regional government level, and for businesses and private organizations to contribute to rolling back the impact of climate change. Governments also have the option of imposing carbon taxes or carbon trading systems on heavy polluters. Taxing fossil fuels and subsidizing low-emission alternatives provides incentives to accelerate the transition to carbon-neutral energy sources.

However, according to World Nuclear Association, [82], there is very popular support for the use of renewable energy, especially solar and wind energy, which provides electricity without giving rise to carbon dioxide emissions. Their operation for electricity depends on the cost and efficiency of the technology, which is constantly improving, thus reducing costs per peak kilowatt and kWh at the source. The use of solar and wind energy in a grid is becoming problematic at high levels for complex reasons, but now well demonstrated. Supply does not match demand. Spare generating capacity is required due to the intermittent nature of the sun and wind. The costs of the system are later with an increasing proportion of variable renewables. Policy settings to support renewable energy sources are generally needed to prioritize and subsidize grid systems, and about 50 countries have

these provisions. The use of solar and wind electricity in an autonomous system requires a suitable battery or other storage capacities. The possibility of widespread use of hydrogen in the future as a transport fuel increases the potential for both renewable sources and basic power supply.

The limitations of the study can be highlighted, on the one hand, by the fact that the analysis only involves the analysis of a panel of ten CEEC and, thus, in a future research other countries will also be included in the model. On the other hand, as threats to climate change become increasingly diverse in the future, other macroeconomic variables could be included in the proposed model.

References

1. Munich Reinsurance Company. *Natural Catastrophe Review 2018*; Geo Risks Research, NatCatSERVICE; Munich Reinsurance Company: Munich, Germany, 2019.
2. Intergovernmental Panel on Climate Change (IPCC). *Global Warming of 1.5 °C, Summary for Policymakers*; Intergovernmental Panel on Climate Change (IPCC): Geneva, Switzerland, 2018.
3. Burke, M.; Hsiang, S.M.; Miguel, E. Global Non-Linear Effect of Temperature on Economic Production. *Nature* **2015**, *527*, 235–239. [CrossRef]
4. Network for Greening the Financial System. *A Call for Action. Climate Change as a Source of Financial Risk*; First comprehensive report; Network for Greening the Financial System: London, UK, 2019.
5. European Commission. *Action Plan: Financing Sustainable Growth*; European Commission: Brussels, Belgium, 2018.
6. The Climate Action in Financial Institutions. G20 Green Finance Synthesis Report, September 2016. Available online: http://unepinquiry.org/wp-content/uploads/2016/09/Synthesis_Report_Full_EN.pdf. (accessed on 4 September 2020).
7. OECD. *Mobilising Bond Markets for a Low-Carbon Transition*; Organisation for Economic Co-operation and Development: Paris, French, 2017.
8. Ahairwe, P.; Bilal, S. *Boosting EU Climate Finance: Mitigate More without Neglecting Adaptation in Poorer Countries*; Policy Brief; European Centre for Development Policy Management: Maastricht, The Netherlands, 2019.
9. United Nations Environment Programme. Emissions Gap Report. 2019. Available online: https://www.unenvironment.org/resources/emissions-gap-report-2019 (accessed on 1 August 2020).
10. Ge, M.; Friedrich, J. World Resources Institute, 4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors. 2020. Available online: https://www.wri.org/blog/2020/02/greenhouse-gas-emissions-by-country-sector (accessed on 15 August 2020).
11. Businesswire. Analysis on the $28.9 Billion Green Technology & Sustainability Market (2019–2024)—ResearchAndMarkets.com. 2019. Available online: https://www.businesswire.com/news/home/20190924005777/en/Analysis-28.9-Billion-Green-Technology-Sustainability-Market (accessed on 15 September 2020).
12. Mathews, J.; Lee, K. Green Development, Innovation and Intellectual Property Rights. 2014. Available online: http://regardssurlaterre.com/en/green-development-innovation-and-intellectual-property-rights (accessed on 20 August 2020).
13. Cloete, S. The Dangers of Green Technology-Forcing. 2018. Available online: https://energypost.eu/the-dangers-of-green-technology-forcing (accessed on 7 September 2020).
14. International European Agency. *Batteries and Hydrogen Technology: Keys for a Clean Energy Future*; IEA: Paris, French, 2020. Available online: https://www.iea.org/articles/batteries-and-hydrogen-technology-keys-for-a-clean-energy-future (accessed on 14 September 2020).
15. Grossman, G.M.; Krueger, A.B. Economic-Growth and the Environment. *Q. J. Econ.* **1995**, *110*, 353–377. [CrossRef]

16. Selden, T.M.; Song, D. Environmental quality and development: Is there a Kuznets curve for air pollution emissions? *J. Environ. Econ. Manag.* **1994**, *27*, 147–162. [CrossRef]

17. Stern, D. The Rise and Fall of the Environmental Kuznets Curve. *Word Dev.* **2004**, *32*, 1419–1438. [CrossRef]

18. Lanoie, P.; Laplante, B.; Roy, M. Can capital markets create incentives for pollution control? *Ecol. Econ.* **1998**, *26*, 31–41. [CrossRef]

19. Birdsall, N.; Wheeler, D. Trade policy and industrial pollution in Latin America: Where are the pollution havens? *J. Environ. Dev.* **1993**, *2*, 137–149. [CrossRef]

20. Frankel, J.; Romer, D. Does trade cause growth? *Am. Econ. Rev.* **1999**, *89*, 379–399. [CrossRef]

21. Frankel, J.; Rose, A. An estimate of the effect of common currencies on trade and income. *Q. J. Econ.* **2002**, *117*, 437–466. [CrossRef]

22. Dasgupta, S.J.; Hong, H.; Laplante, B.; Mamingi, N. Disclosure of environmental violations and the stock market in the Republic of Korea. *Ecol. Econ.* **2004**, *58*, 759–777. [CrossRef]

23. Wang, H.; Jin, Y. Industrial ownership and environmental performance: Evidence from China. *Environ. Resour. Econ.* **2007**, *36*, 255–273. [CrossRef]

24. Bello, A.K.; Abimola, Q.M. Does the level of Economic Growth influence Environmental Quality in Nigeria: A test of environmental Kuznets curve (EKC) Hypothesis, Pakistan. *J. Soc. Sci.* **2010**, *7*, 325–329. [CrossRef]

25. Islam, F.; Shahbaz, M.; Ahmed, A.U.; Alam, M.M. Financial development and energy consumption nexus in Malaysia: A multivariate time series analysis. *Econ. Model.* **2013**, *30*, 435–441. [CrossRef]

26. Ang, J.B. CO_2 emissions, energy consumption, and output in France. *Energy Policy* **2007**, *35*, 4772–4778. [CrossRef]

27. Apergis, N.; Payne, J.E. CO_2 emissions, energy usage, and output in Central America. *Energy Policy* **2009**, *37*, 3282–3286. [CrossRef]

28. Kumbaroglu, G.; Karali, N.; Arıkan, Y. CO_2, GDP and RET: An aggregate economic equilibrium analysis for Turkey. *Energy Policy* **2008**, *36*, 2694–2708. [CrossRef]

29. Claessens, S.; Feijen, E. Financial sector development and the millennium development goal. *World Bank* **2007**. [CrossRef]

30. Aldy, J.E. An environmental Kuznets curve analysis of US state-level carbon dioxide emissions. *J. Environ. Dev.* **2005**, *14*, 48–72. [CrossRef]

31. Acaravci, A.; Ozturk, I. On the relationship between energy consumption, CO_2 emissions and economic growth in Europe. *Energy* **2010**, *35*, 5412–5420. [CrossRef]

32. Apergis, N.; Ozturk, I. Testing the environmental Kuznets hypothesis in Asian countries. *Ecol. Indic.* **2015**, *52*, 16–22. [CrossRef]

33. Hossain, M.S. Panel estimation for CO_2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. *Energy Policy* **2011**, *39*, 6991–6999. [CrossRef]

34. Niu, S.; Ding, Y.; Niu, Y.; Li, Y.; Luo, G. Economic growth, energy conservation and emissions reduction: A comparative analysis based on panel data for 8 Asian Pacific countries. *Energy Policy* **2011**, *39*, 2121–2131. [CrossRef]

35. Zakarya, G.Y.; Mostefa, B.; Abbes, S.M.; Seghir, G.M. Factors Affecting CO_2 Emissions in the BRICS Countries: A Panel Data Analysis. *Procedia Econ. Financ.* **2015**, *26*, 114–125. Available online: www.sciencedirect.com (accessed on 14 September 2020). [CrossRef]

36. Bekhet, H.; Mustapa, S.I. Factors Influencing CO_2 Emissions and Strategies for Emissions Re-duction in Malaysian Transportation Sector. *Int. J. Eng. Technol.* **2018**, *7*. [CrossRef]

37. Shahbaz, M.; Jam, F.A.; Bibi, S.; Loganathan, N. Multivariate granger causality between CO_2 emissions, energy intensity and economic growth in Portugal: Evidence from cointegration and causality analysis. *Technol. Econ. Dev. Econ.* **2016**. [CrossRef]

38. Yuxiang, K.; Chen, Z. Financial development and environmental performance: Evidence from China. *Environ. Dev. Econ.* **2011**, *16*, 93–111. [CrossRef]

39. Xing, T.; Jiang, Q.; Ma, X. To facilitate or curb? The role of financial development in China's carbon emissions reduction process: A novel approach. *Int. J. Environ. Res. Public Health* **2017**, *14*, 12–22. [CrossRef]

40. Park, Y.; Meng, F.; Baloch, M.A. The effect of ICT, financial development, growth, and trade openness on CO_2 emissions: An empirical analysis. *Environ. Sci. Pollut. Res.* **2018**, *25*, 708–719. [CrossRef]

41. Tamazian, A.; Chousa, J.P.; Vadlamannati, K.C. Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. *Energy Policy* **2009**, *37*, 246–253. [CrossRef]

42. Shahbaz, M. A reassessment of finance-growth nexus for Pakistan: Under the investigation of FMOLS and DOLS techniques. *ICFAI J. Appl. Econ.* **2009**, *1*, 65–80.

43. Chebbi, H.E.; Olarreaga, M.; Zitouna, H. Trade openness and CO_2 emissions in Tunisia. *Middle East Dev. J.* **2011**, *3*, 29–53. [CrossRef]

44. Jalil, A.; Feridun, M. The impact of growth, energy and financial development on the environment in China: A cointegration analysis. *Energy Econ.* **2011**, *33*, 284–291. [CrossRef]

45. Abbasi, F.; Riaz, K. CO_2 emissions and financial development in an emerging economy: An augmented VAR approach. *Energy Policy* **2016**, *90*, 102–114. [CrossRef]

46. Yang, L.; Yuan, S.; Sun, L. The Relationship between Economic Growth and Environmental Pollution Based on Time Series Data: An Empirical Study of Zhejiang Province. *J. Camb. Stud.* **2012**, *7*, 33–42.

47. Lee, J.-M.; Chen, K.-H.; Cho, C.-H. The relationship between CO_2 emissions and financial development: Evidence from OECD countries. *Singap. Econ. Rev.* **2015**, *60*, 1550117. [CrossRef]

48. Halkos, G.E.; Tzeremes, N.G. The effect of electricity consumption from renewable sources on countries economic growth levels: Evidence from advanced, emerging and developing economies. *Renew. Sustain. Energy Rev.* **2014**, *39*, 166–173. [CrossRef]

49. Nihal, M.; Mansur, M. Dynamics between Islamic Banking Performance and CO_2 Emissions: Evidence from the OIC Countries. MPRA Paper No. 9565. 2018. Available online: https://mpra.ub.uni-muenchen.de/95652/ (accessed on 12 August 2020).

50. Shah, W.U.H.; Yasmeen, R.; Padda, I.U.H. An analysis between financial development, institutions, and the environment: A global view. *Environ. Sci. Pollut. Res.* **2019**, *26*, 21437–21449. [CrossRef]

51. Jiang, C.; Ma, X. The Impact of Financial Development on Carbon Emissions: A Global Perspective. *Sustainability* **2019**, *11*, 5241. [CrossRef]

52. Zhou, Y.; Fang, Z.; Li, N.; Wu, X.; Du, Y.; Liu, Z. How Does Financial Development Affect Reductions in Carbon Emissions in High-Energy Industries?—A Perspective on Technological Progress. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3018. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6747364 (accessed on 10 August 2020). [CrossRef]

53. Word Population Review. CO_2 Emissions by Country 2020. Available online: https://worldpopulationreview.com/country-rankings/co2-emissions-by-country (accessed on 12 August 2020).

54. Eurostat. Greenhouse Gas Emissions by Individuals and Household. Analysis by Economic Activity, February 2020. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Greenhouse_gas_emissions_by_industries_and_households#Analysis_by_economic_activity (accessed on 3 August 2020).

55. European Environment Agency (EEA). Trends and Drivers of EU Greenhouse Gas Emissions, March 2020. Available online: https://www.eea.europa.eu/publications/trends-and-drivers-of-eu-ghg/download (accessed on 5 August 2020).

56. International Energy Agency. Global Energy & CO_2 Status Report 2019. The Latest Trends in Energy and Emissions in 2018. March 2019. Available online: https://www.iea.org/reports/global-energy-co2-status-report-2019/emissions (accessed on 19 August 2020).

57. Shell Hydrogen Study. Energy of the Future? Sustainable Mobility through Fuel Cells and H2. Shell Deutschland Oil GmbH22284 Hamburg. 2020. Available online: https://hydrogeneurope.eu/sites/default/files/shell-h2-study-new.pdf (accessed on 12 September 2020).

58. Mayyas, A.T.; Ruth, M.F.; Pivovar, B.S.; Bender, G.; Wipke, K.B. *Manufacturing Cost Analysis for Proton Exchange Membrane Water Electrolyzers*; Technical Report NREL/TP-6A20-72740; National Renewable Energy Laboratory: Golden, CO, USA, 2019. Available online: https://www.nrel.gov/docs/fy19osti/72740.pdf (accessed on 12 September 2020).

59. Fitzgerald, L.; Brauers, H. Sustainable-Energy-Policy-In-Germany-A-Case-Of-Natural-Gas-Lock-In. 2019. Available online: https://www.resilience.org/stories/2019-11-25/sustainable-energy-policy-in-germany-a-case-of-natural-gas-lock-in (accessed on 12 September 2020).

60. Eriksen, F. Most Germans Who Switch Energy Source in Heating Opt for Natural Gas-Study. 2019. Available online: https://www.cleanenergywire.org/news/most-germans-who-switch-energy-source-heating-opt-natural-gas-study (accessed on 12 September 2020).

61. Union of Concerned Scientists. Environmental Impacts of Natural Gas. 2014. Available online: https://www.ucsusa.org/resources/environmental-impacts-natural-gas (accessed on 16 August 2020).

62.	Alvarez, R.A.; Pacala, S.W.; Winebrake, J.J.; Chameides, W.L.; Hamburg, S.P. Greater focus needed on methane leakage from natural gas infrastructure. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 6435–6440. [CrossRef]

63.	Wettengel, J. Germany's Dependence on Imported Fossil Fuels. 2020. Available online: https://www.cleanenergywire.org/factsheets/germanys-dependence-imported-fossil-fuels (accessed on 9 September 2020).

64.	Climate Action Network Europe. *Off. Target Ranking of EU Countries' Ambition and Progress in Fighting Climate Change*; Climate Action Network Europe: Brussels, Belgium, 2018. Available online: http://www.caneurope.org/docman/climate-energy-targets/3357-off-target-ranking-of-eu-countries-ambition-and-progress-in-fighting-climate-change/file (accessed on 18 August 2020).

65.	Armeanu, D.; Vintilă, G.; Andrei, J.V.; Gherghina, Ş.C.; Drăgoi, M.C.; Teodor, C. Exploring the link between environmental pollution and economic growth in EU-28 countries: Is there an environmental Kuznets curve? *PLoS ONE* **2018**, *13*, e0195708. [CrossRef]

66.	He, J.; Richard, P. Environmental Kuznets curve for CO_2 in Canada. *Ecol. Econ.* **2010**, *69*, 1083–1093. [CrossRef]

67.	Levin, A.; Lin, C.F.; Chu, C. Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties. *J. Econom.* **2002**, *108*, 1–24. [CrossRef]

68.	Engle, R.F.; Granger, C.W.J. Cointegration and Error Correction: Representation, Estimation and Testing. *Econometrica* **1987**, *55*, 251–276. [CrossRef]

69.	Pedroni, P. Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxf. Bull. Econ. Stat.* **1999**, *61*, 653–670. [CrossRef]

70.	Pedroni, P. Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econom. Theory* **2004**, *20*, 597–625. [CrossRef]

71.	Fisher, R.A. *Statistical Methods for Research Workers*, 4th ed.; Oliver & Boyd: Edinburgh, UK, 1932.

72.	Phillips, P.; Hansen, B. Statistical Inference in Instrumental Variables Regression with I (1) Processes. *Rev. Econ. Stud.* **1990**, *57*, 99–125. [CrossRef]

73.	Pedroni, P. *Fully Modified OLS for Heterogeneous Cointegrated Panels*; No 2000-03; Department of Economics Working Papers, Department of Economics, Williams College: Williamstown, MA, USA, 2000.

74.	INSSE. Available online: https://insse.ro/cms/files/Web_IDD_BD_ro/index.htm (accessed on 21 July 2020).

75.	Brandt, U.S.; Svendsen, G.T. A Global CO_2 Tax for Sustainable Development. *J. Sustain. Dev.* **2014**, *7*, 85–93. [CrossRef]

76.	Zimmermannova, J.; Hajek, M.; Rozensky, L. Carbon Taxation in the European Countries. In Proceedings of the 22nd International Conference on Theoretical and Practical Aspects of Public Finance, Prague, Czech Republic, 7–8 April 2017; Volume 22.

77.	Miller, S.J.; Vela, M.A. *Are Environmentally Related Taxes Effective*; Working Paper Series; Inter-American Development Bank: Washington, DC, USA, 2013; Volume 467.

78.	Jula, D.; Dumitrescu, C.I.; Lie, I.R.; Dobrescu, R. Environmental Kuznets curve. Evidence from Romania. *Theor. Appl. Econ.* **2015**, *1*, 85–96.

79.	Maddala, G.S.; Wu, S. A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test. *Oxf. Bull. Econ. Stat.* **1999**, *61*, 631–652. [CrossRef]

80.	Lagarde, C. Climate Change and the Financial Sector. In Proceedings of the COP 26 Private Finance Agenda, London, UK, 27 February 2020.

81.	European Commission. *Special Eurobarometer 490—Climate Change*; European Commission: Brussels, Belgium, 2019.

82.	World Nuclear Association. Renewable Energy and Electricity. August 2020. Available online: https://www.world-nuclear.org/information-library/energy-and-the-environment/renewable-energy-and-electricity.aspx (accessed on 7 September 2020).